BEAM SHAPE AND LUMINOSITY AT DØ

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- Beamshape and luminosity ratio
- Optics change:
  - what we saw in the beam
  - what we got in luminosity
- Optics change and the DØ/CDF luminosity ratio
- Conclusion

Luminosity integral

$$\mathcal{L} = \frac{f_{\text{rev}} N_1 N_2}{2\pi\beta^*(\epsilon_1+\epsilon_2)} \frac{1}{\sqrt{2\pi}\sigma_z}\int \frac{1}{(1+z^2/\beta^{*2})} \exp[-\frac{z^2}{2\sigma_z^2} - \frac{2z^2}{\sigma_x^2}\theta_x^2 - \frac{2z^2}{\sigma_y^2}\theta_y^2]\, dz$$

Many of us tried to see if the difference between D0 and CDF could be due to the different bunches colliding, but that is not the case.

$$L = \frac{\gamma}{2\pi} f_o B N_p N_{\bar{p}} \frac{H}{\beta^* \varepsilon_p (1 + \varepsilon_{\bar{p}}/\varepsilon_p)}$$

The only difference between D0 and B0 are ***H*** and β*** (=optics) .**

Hourglass factor formula, from M. Church (assuming no crossing angle):

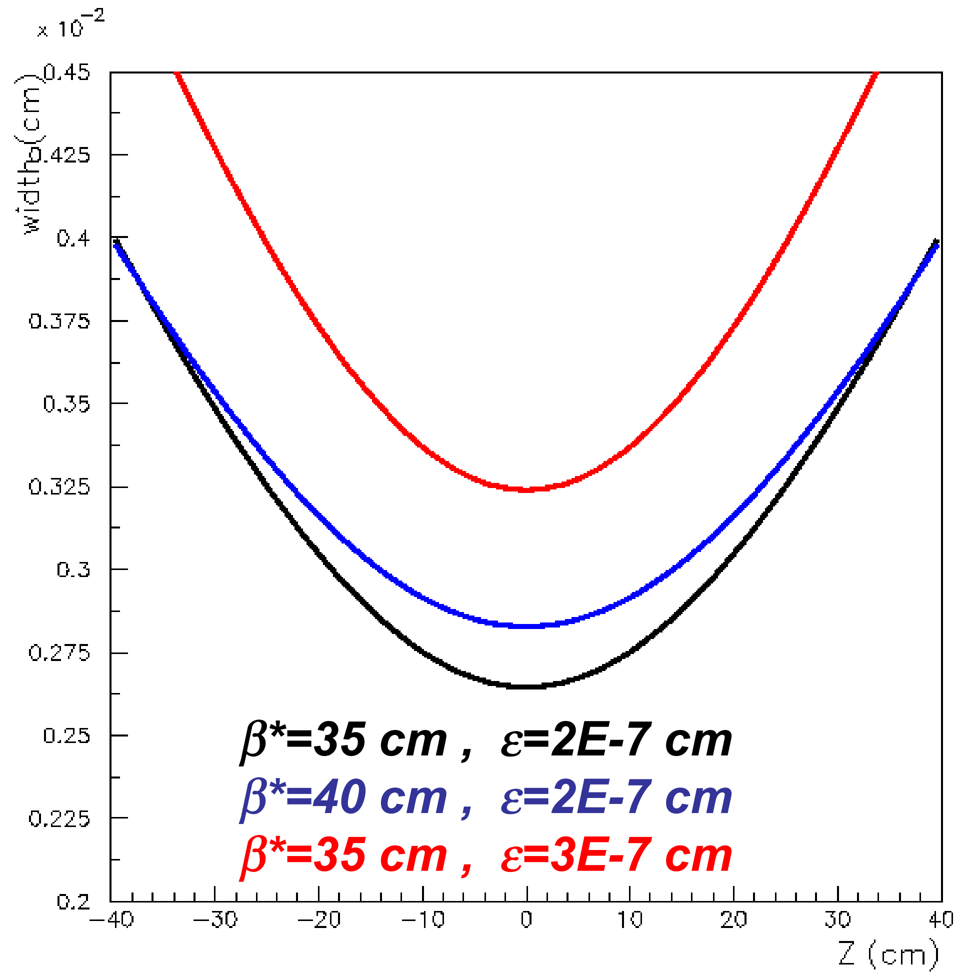
$$H(\overline{\sigma}_L) = 1.1117 - 0.6254\overline{\sigma}_L + 0.19358\overline{\sigma}_L^{\,2} - 0.02442\overline{\sigma}_L^{\,3} \qquad \overline{\sigma}_L = \frac{c\sigma_t}{\beta}$$

Beam shape in the interaction point

The interaction region is a drift in the Tevatron, one expects.

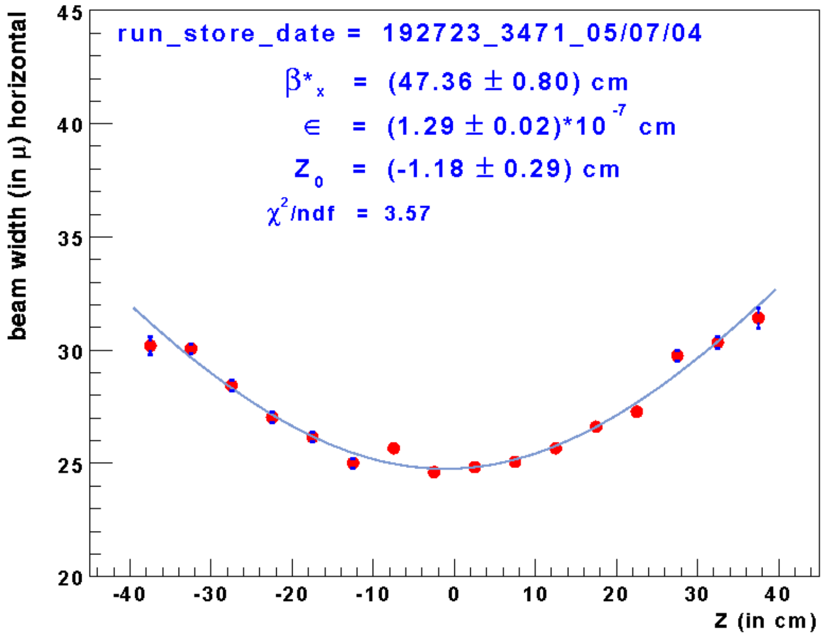
$$\sigma^2 = \varepsilon_{eff}\left[\beta^* + \frac{(z - z_0)^2}{\beta^*}\right]$$

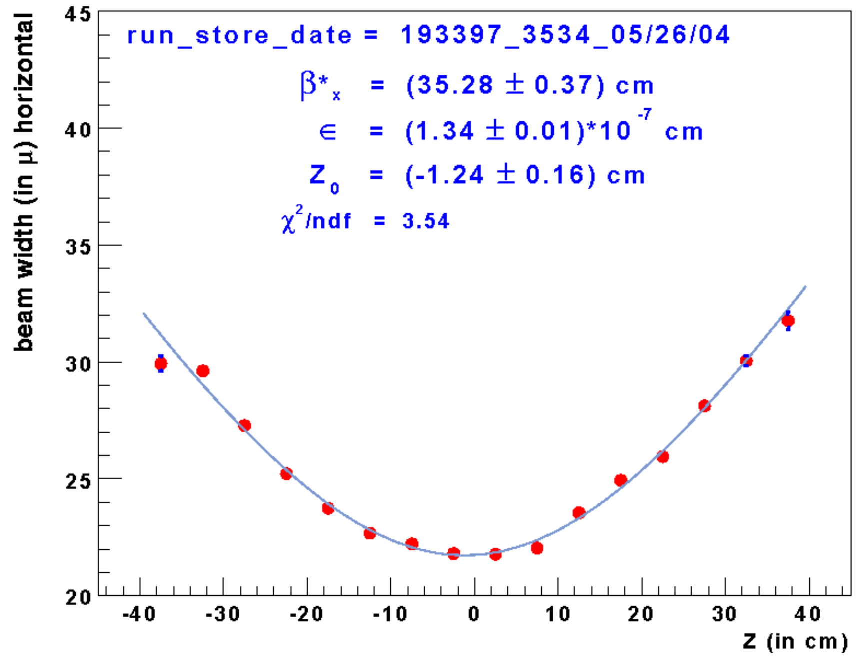
$$\varepsilon_{eff} = \frac{\varepsilon_p \varepsilon_{pbar}}{\varepsilon_p + \varepsilon_{pbar}}$$



In the beams division they expect ***β*=35 cm*.**

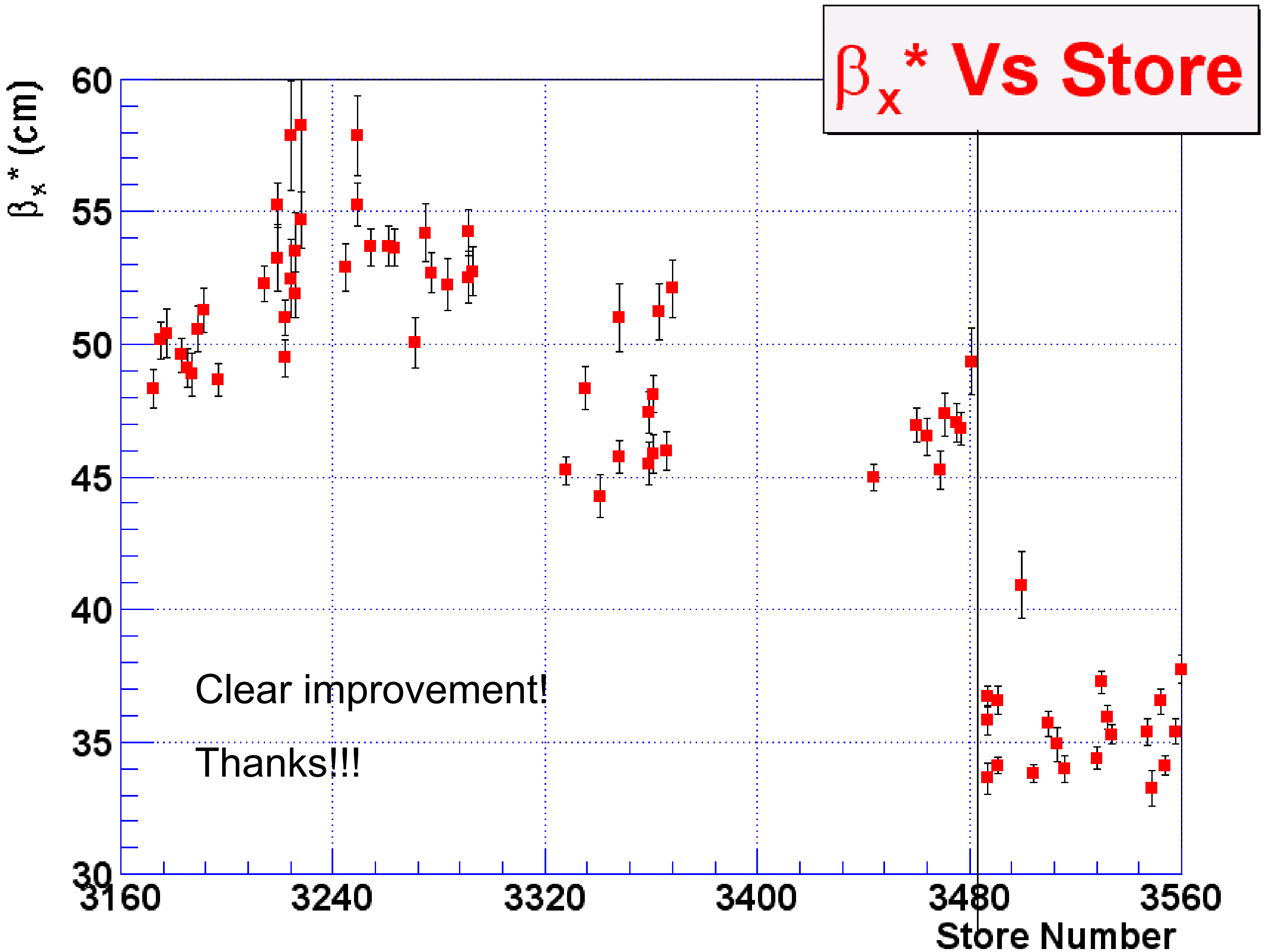
Change in the optics (horizontal)



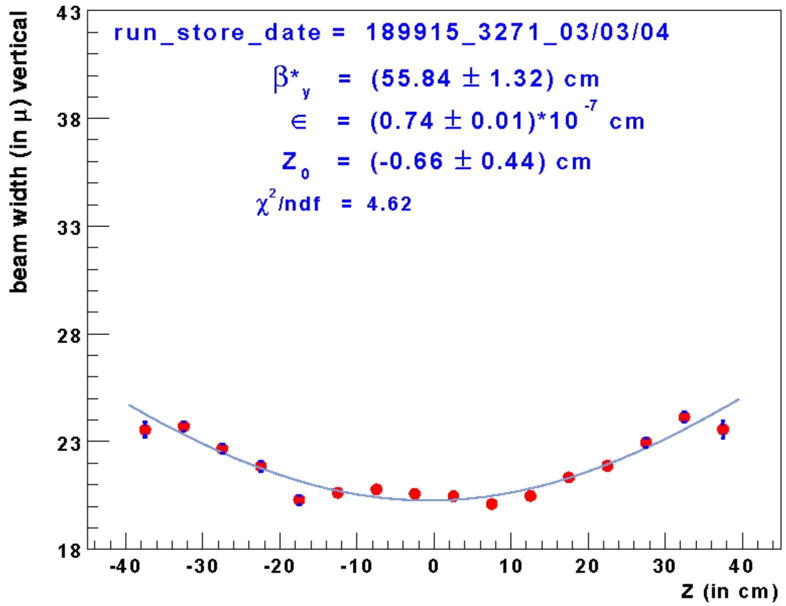


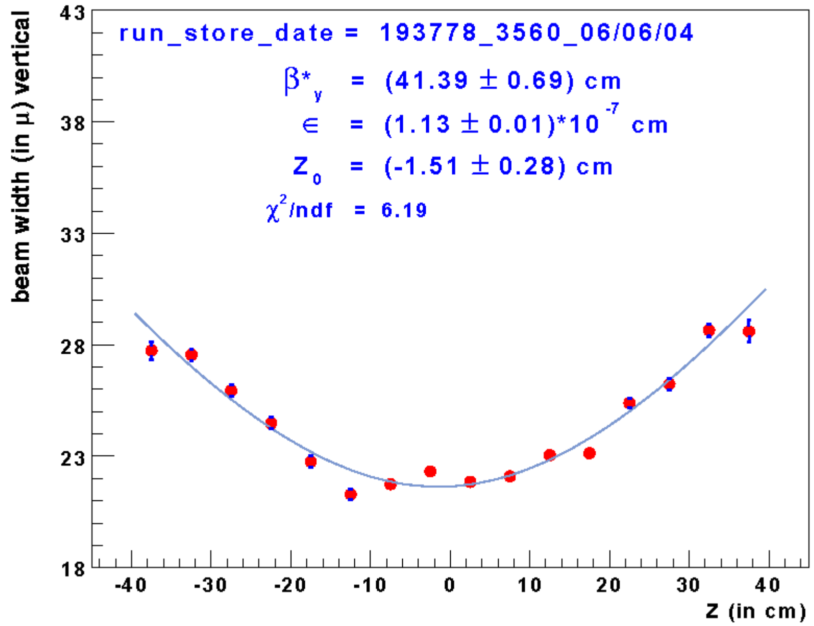
After the optics change, β* moved from ~45cm to the ~35cm (design value) for the horizontal position.

Improvement in β^*_x



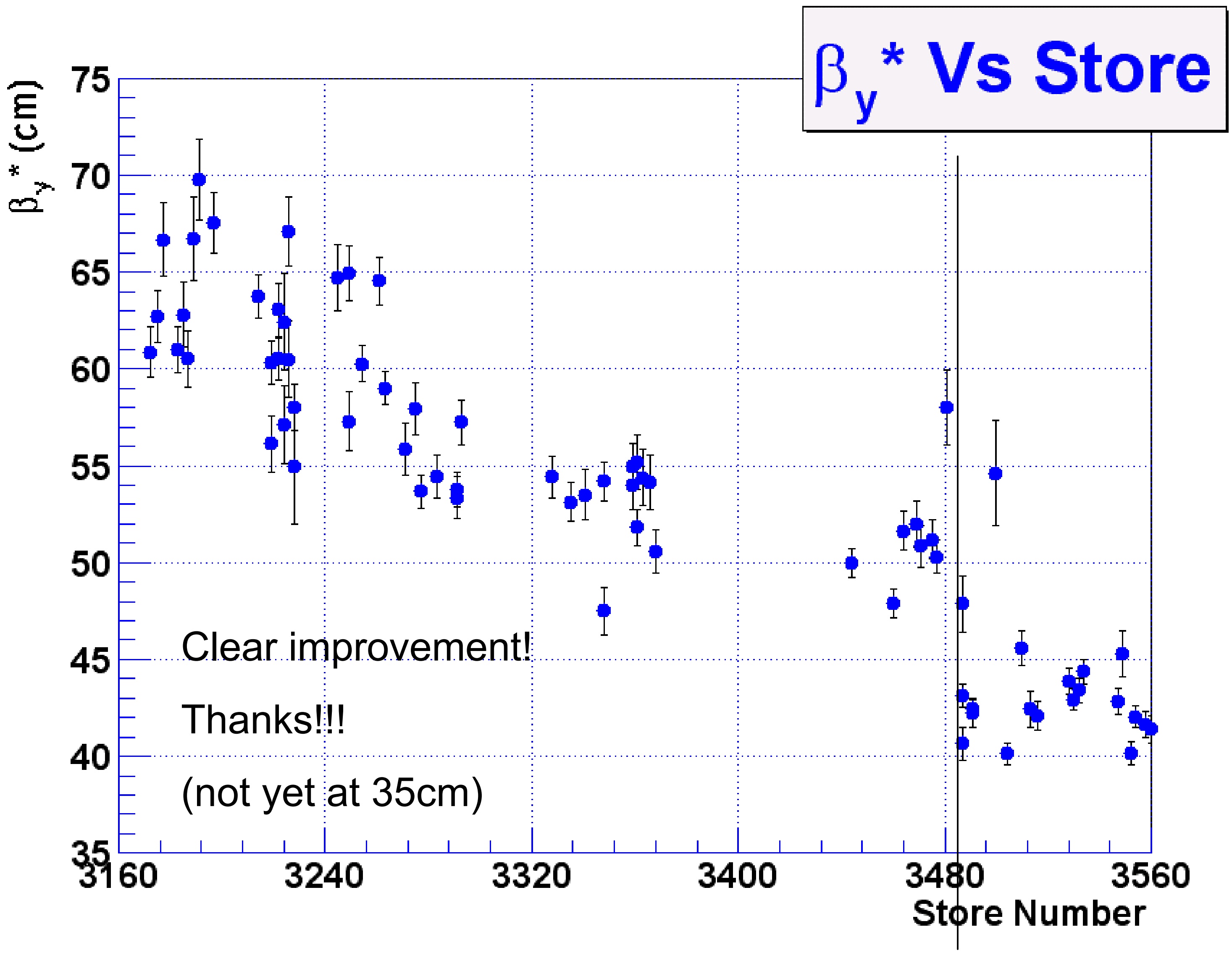
Change in the optics (vertical)



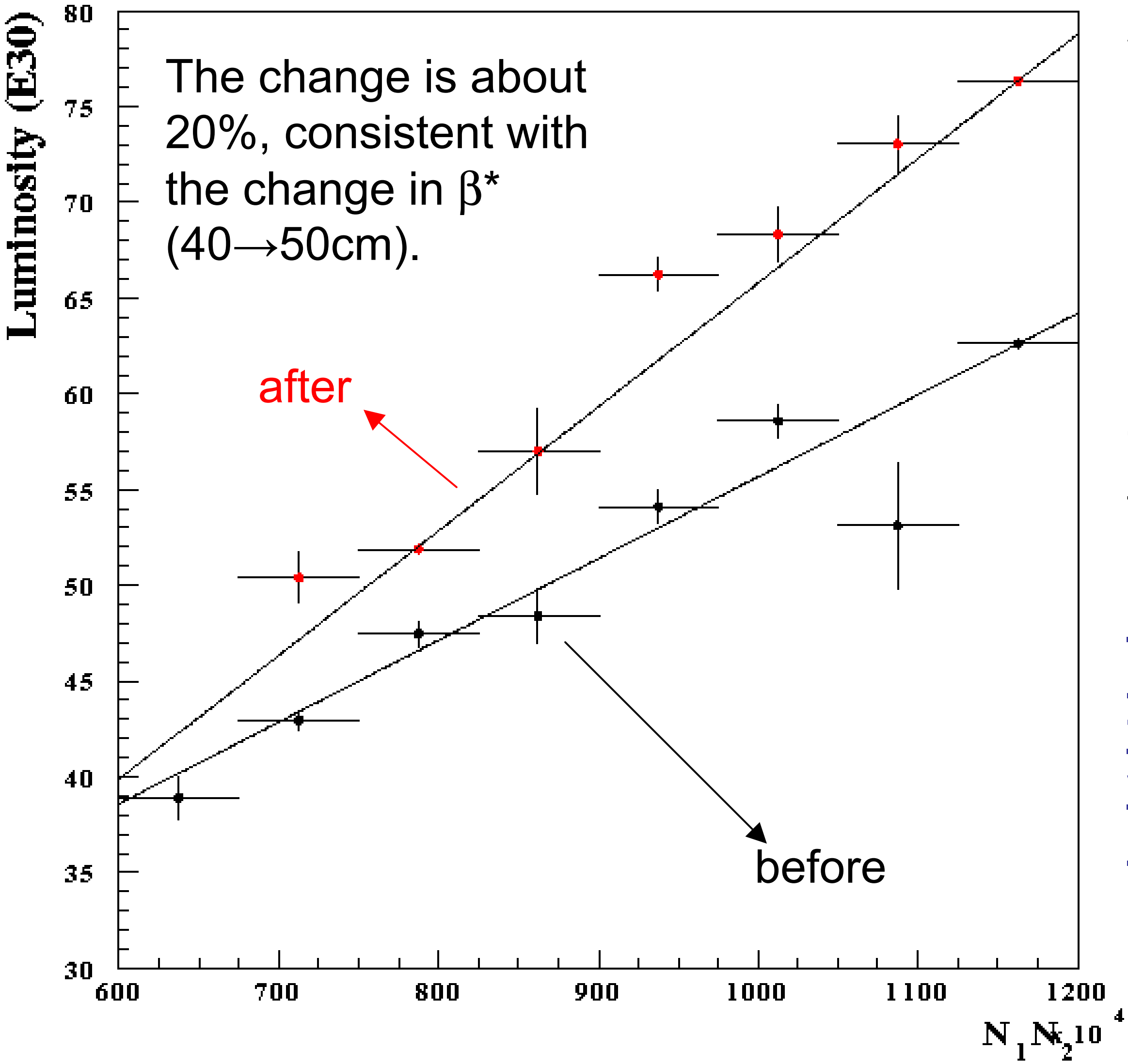


In the vertical direction there was also an improvement, but the shape of the luminous region still has some non-parabolic features.

Improvement in β^*_y



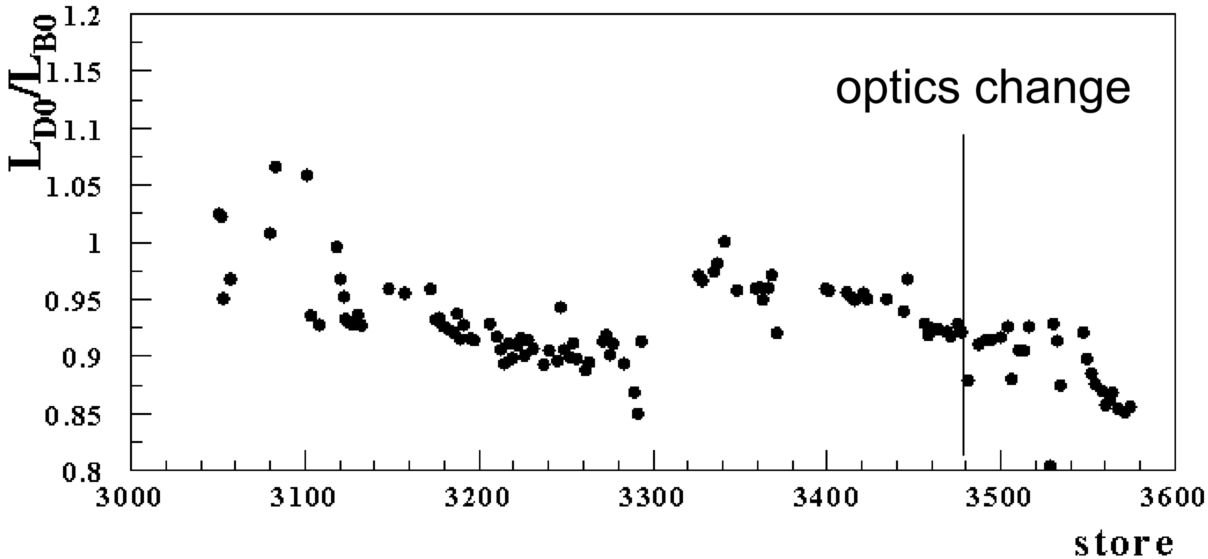
Luminosity Increase with new optics

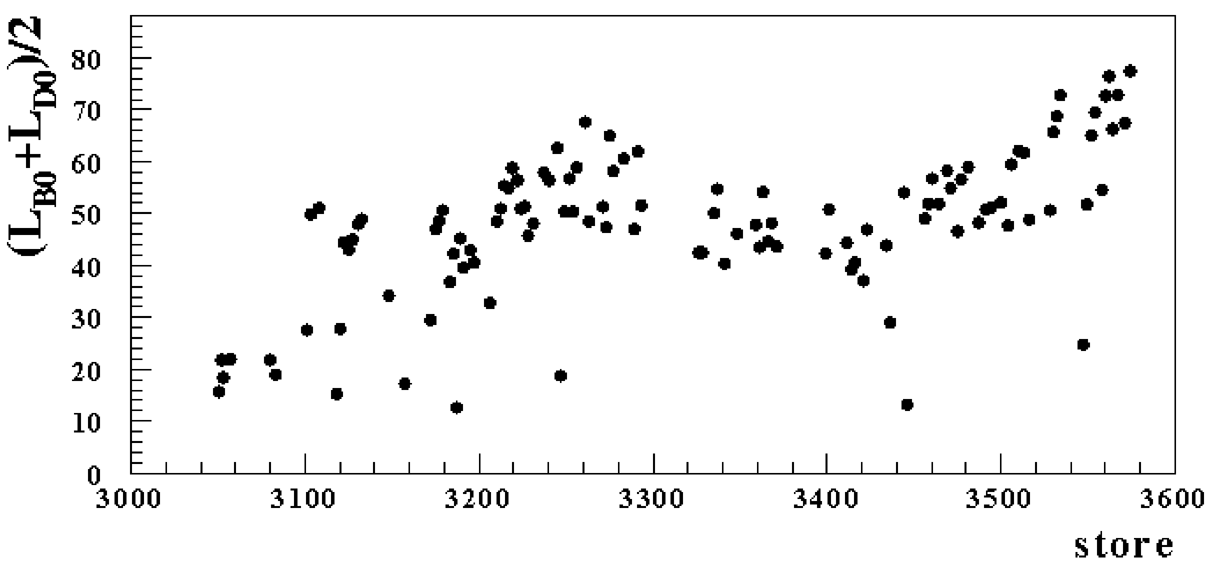


With the new optics, the luminosity when up. That means, that for the same number p and pbar, we get higher luminosities.

This was the ultimate test for our beam shape measurements at DØ. **We can really measure a change in the optics, and the luminosity goes up when we see an improvement in the beam.**

The luminosity ratio (DØ/CDF)





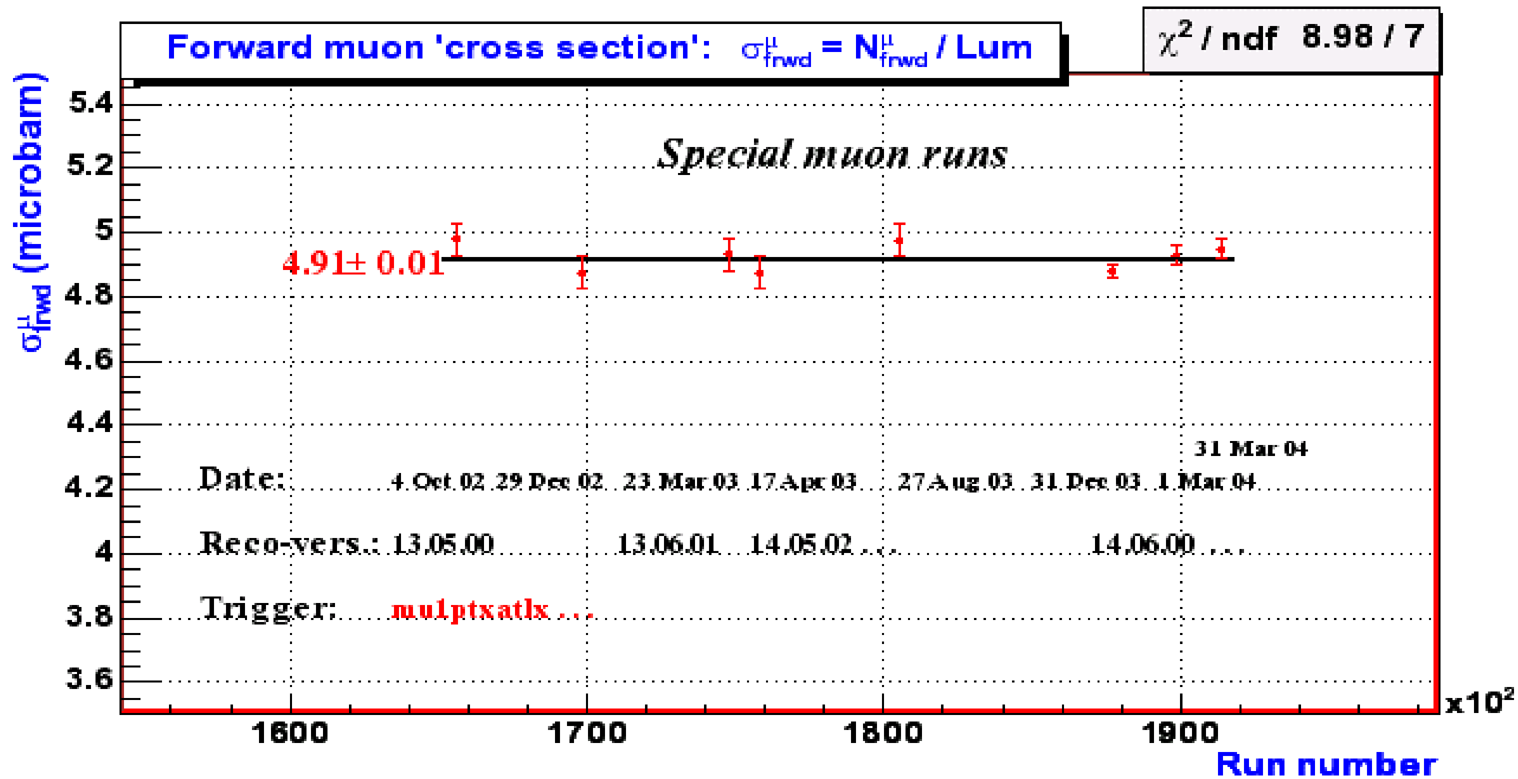
For a long time we have been seen at DØ, less collisions than at CDF. The ratio can be as low as .85, and it is not getting better.

This problem did not improve with the new optics.

CDF also saw an improvement in β* (~25cm).

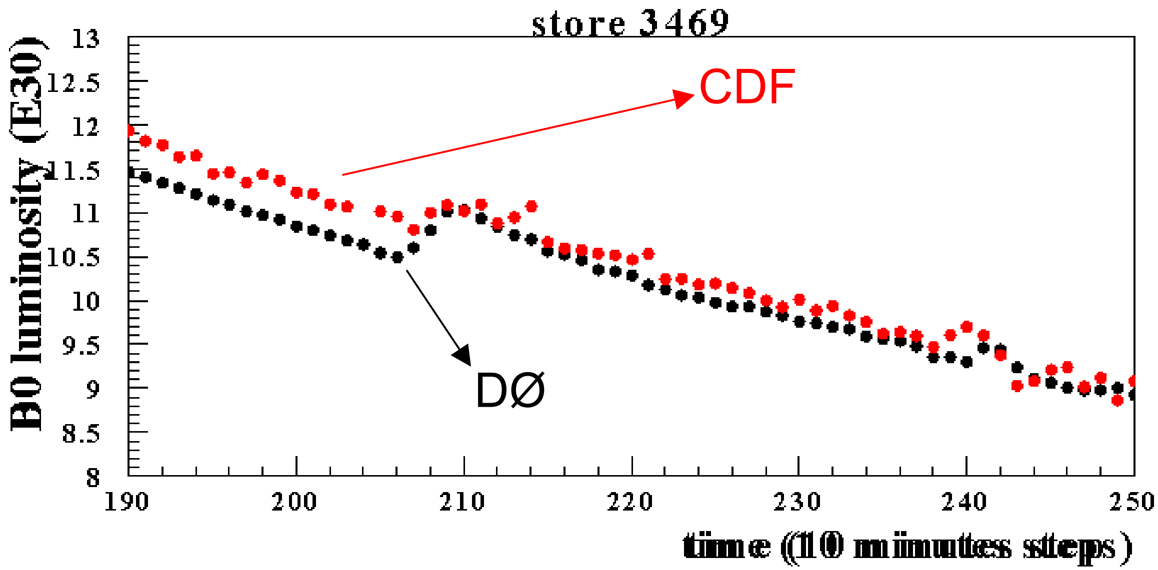
Muon inclusive cross sections

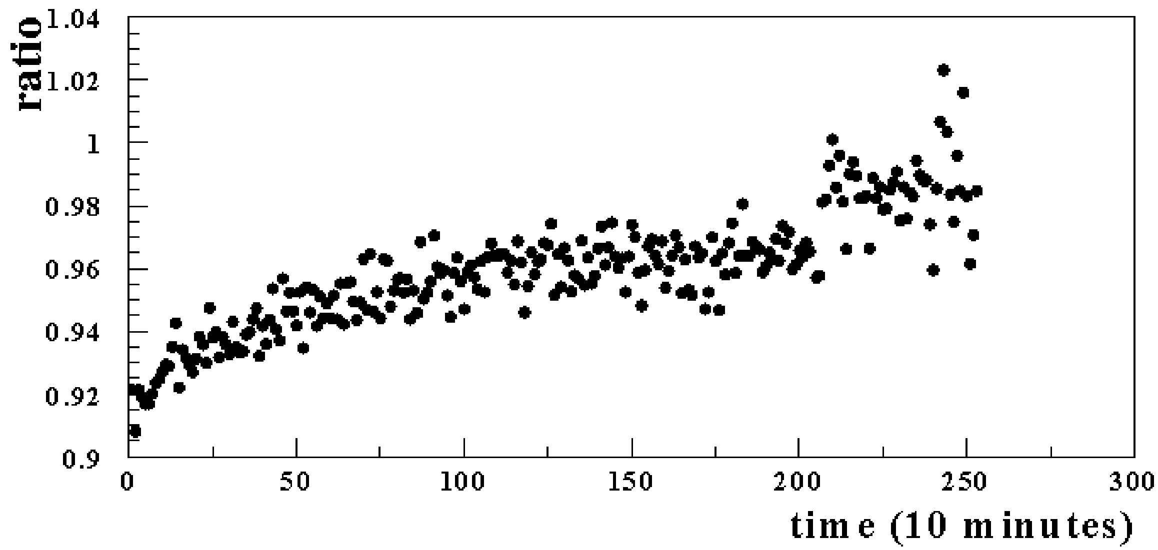
- Naturally tests almost all parts of the muon system and reconstruction and is also a **check of the luminosity measurement**
- Over almost two years provides reliable monitoring on a better than 1% level



We trust our luminosity measurement much better than 10%. CDF also checked their luminosity measurement.

Preliminary optics change

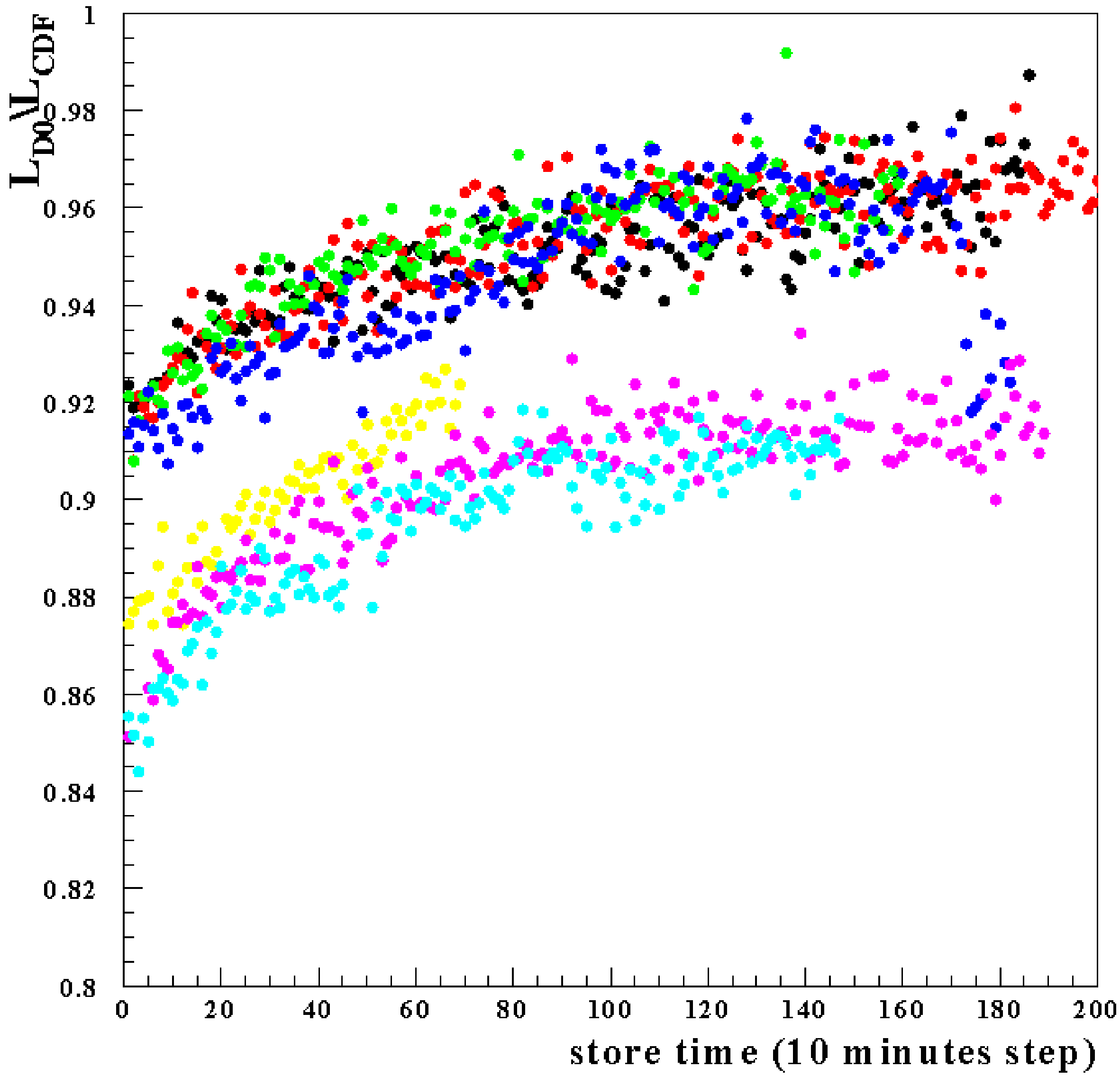




The optics change did not solve the problem of the DØ/CDF luminosity.

However, when some tests where done to prepare for the optics changes, seem like there was a point where the luminosity ratio was ~1.

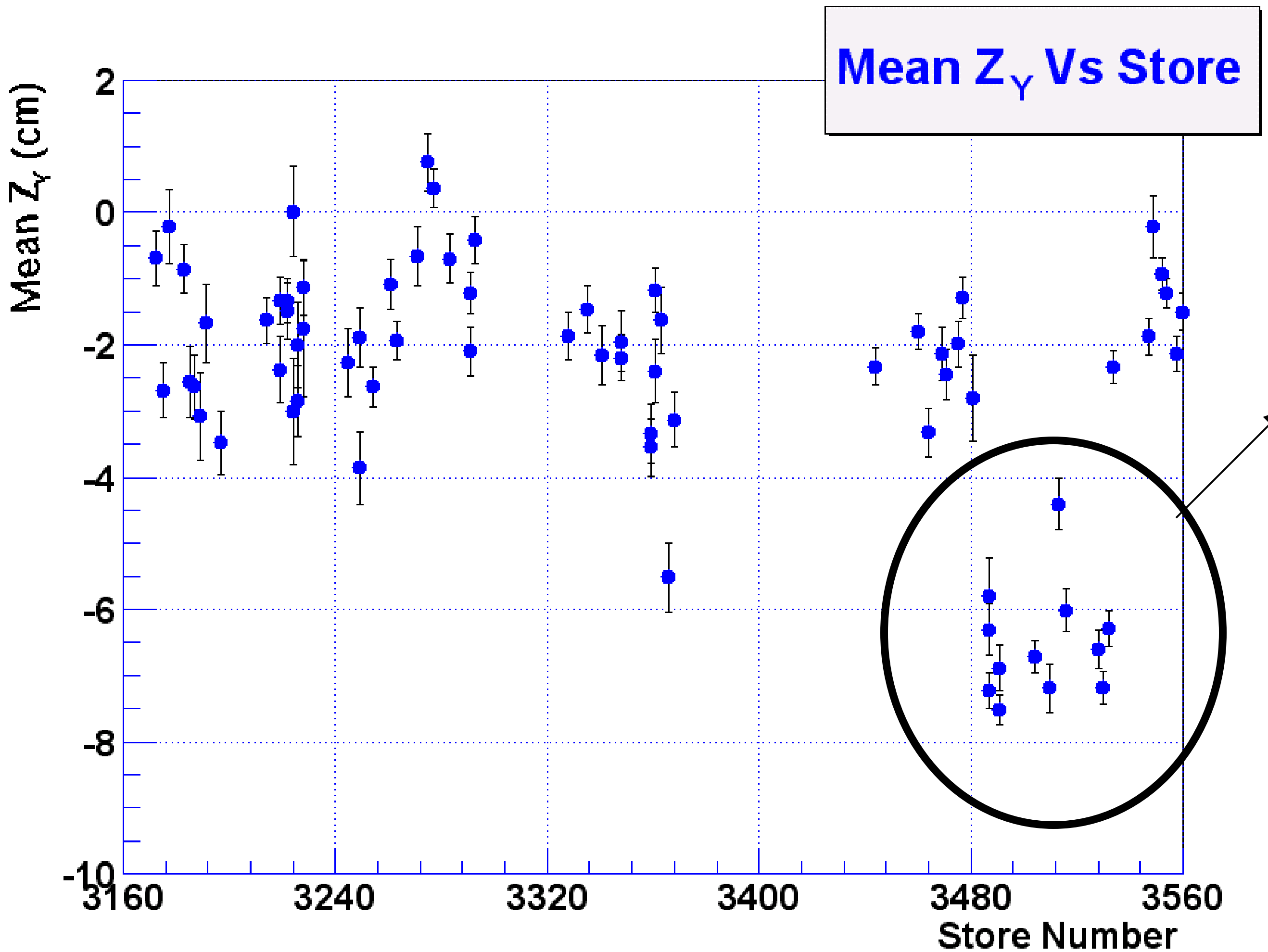
Luminosity ratio during a store (1)



At the end of the store the luminosity ratio is closer to 1. Independent of the initial luminosity.

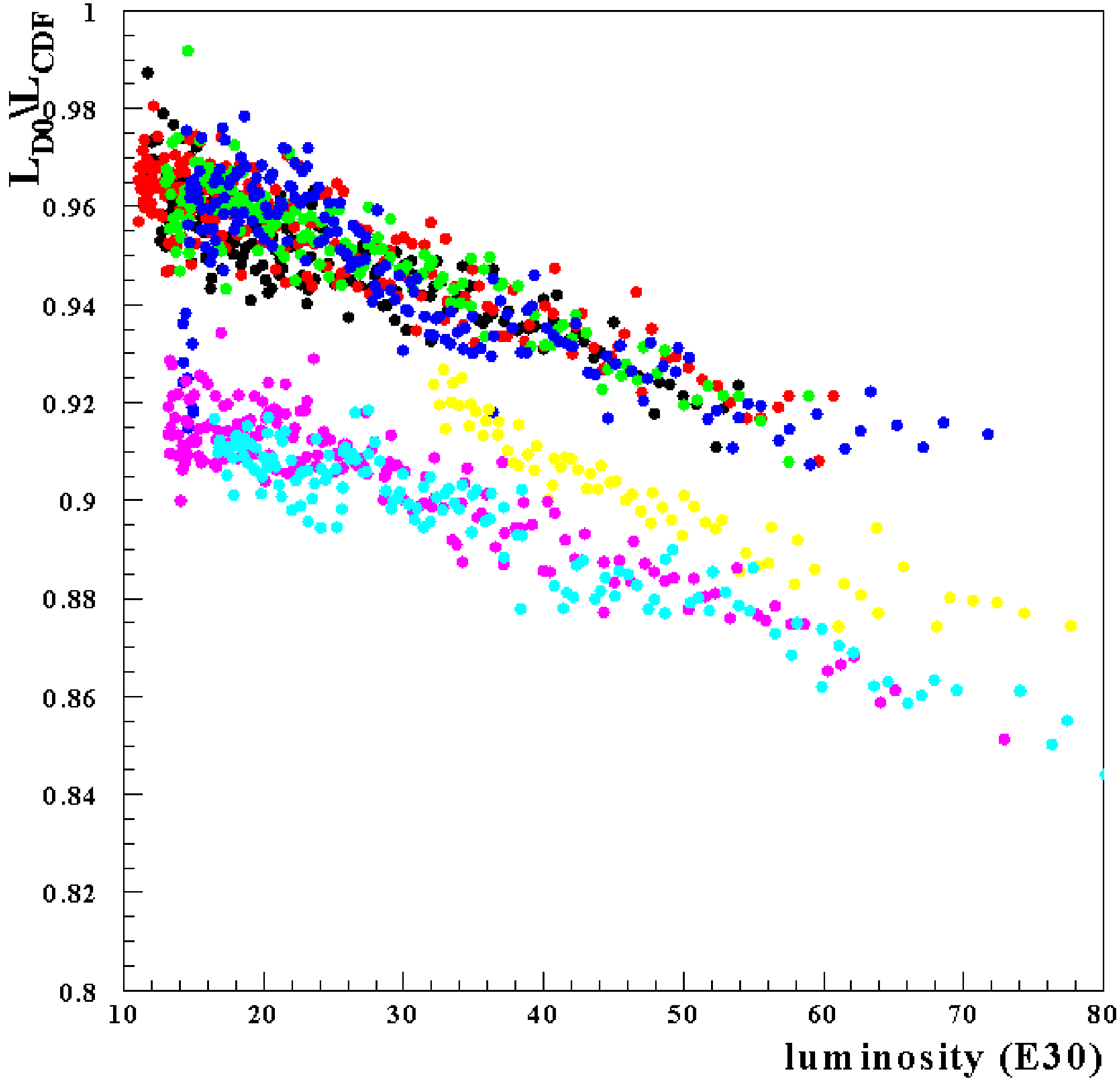
Store luminosity (E30)	
3464	50
3469	56
3477	54
3532	65 (last z offset)
3534	68
3571	62
3574	71

Other changes in the optics



After the optics change, our beam was shifted in Z. We reported this to the Tevatron dept, and the problem was later fixed.

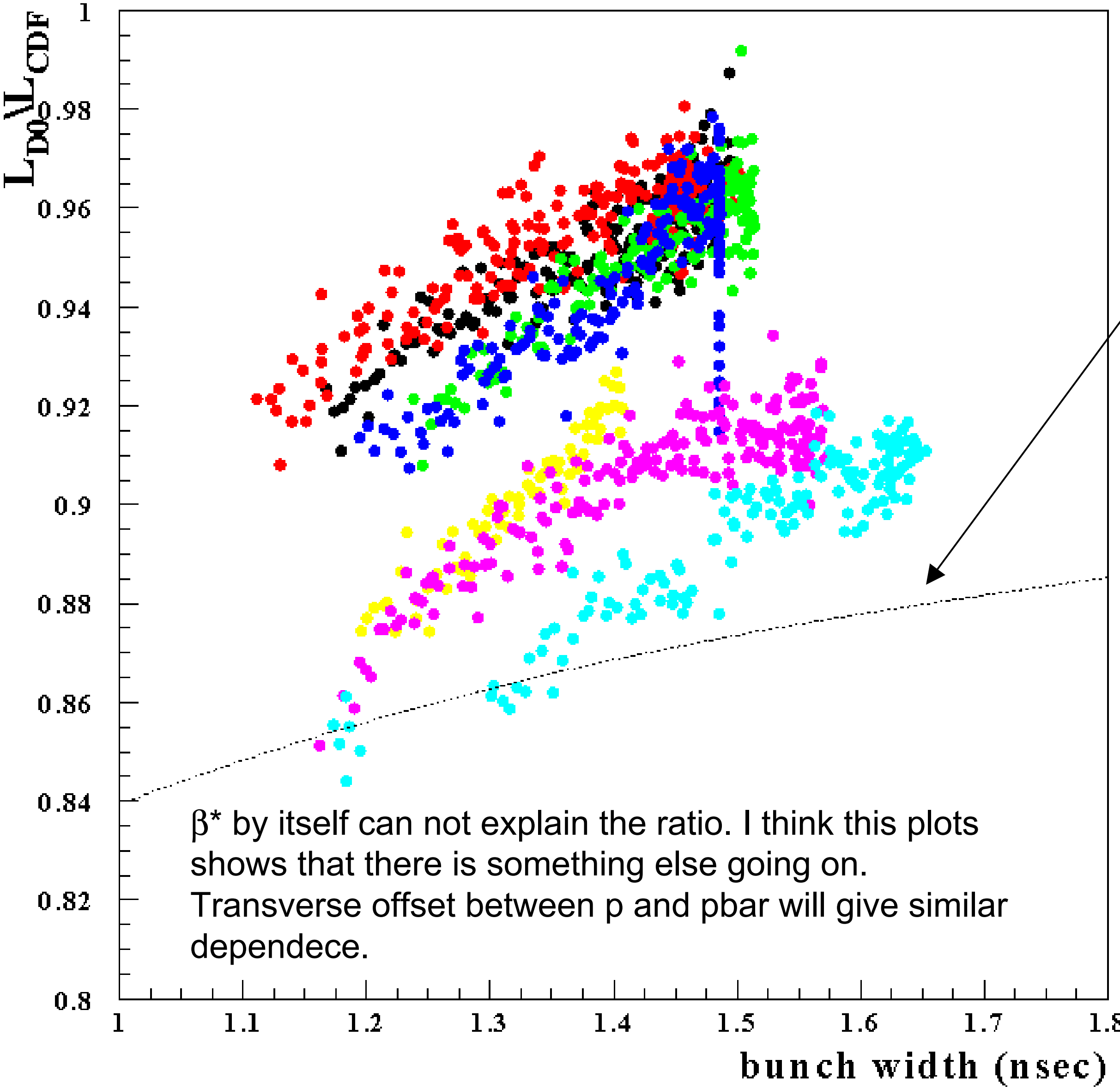
Luminosity ratio during a store (2)



Store	luminosity (E30)
3464	50
3469	56
3477	54
3532	65 (last z offset)
3534	68
3571	62
3574	71

The jump happened at the same time, we got the Z offset fixed.

Luminosity ratio during a store (3)



Assuming that the only difference between DØ and CDF is β* (35 cm vs 25 cm), this is the expected curve.

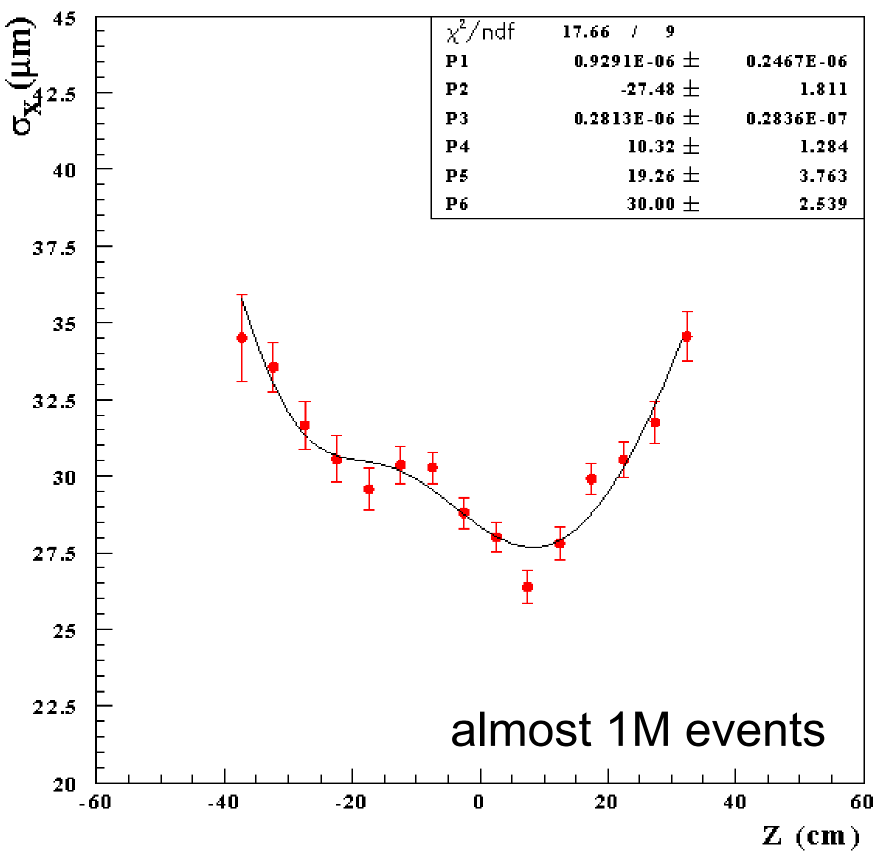
Store luminosity (E30)

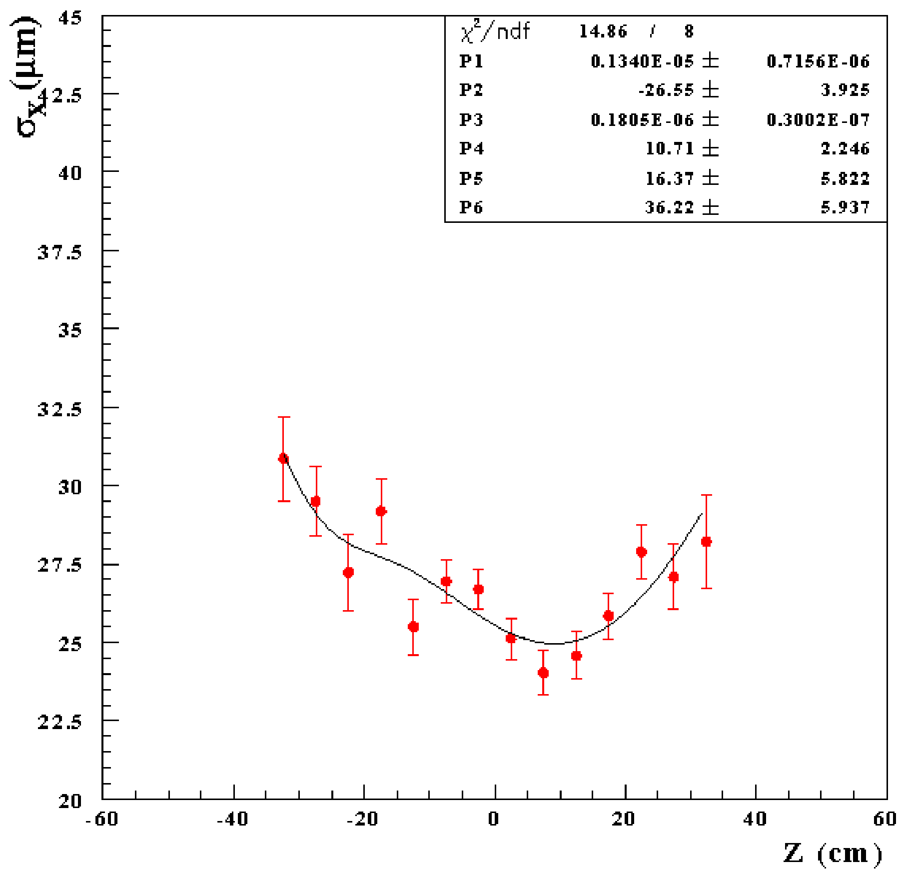
3464	50	} before
3469	56	
3477	54	
3532	65 (last z offset)	
3534	68	
3571	62	
3574	71	

Conclusions

- The effect of the new optics change is clear in our measurements of the beam shape at DØ. We understand why the luminosity went up.
- The new optics did not change the luminosity ratio (DØ/CDF).
- We lost 10% of the luminosity ratio when fixing the Z offset, maybe we can recover this easily. Is this giving us a clue on where the problem is?
- The luminosity ratio is not only determined by the differences in β^*.

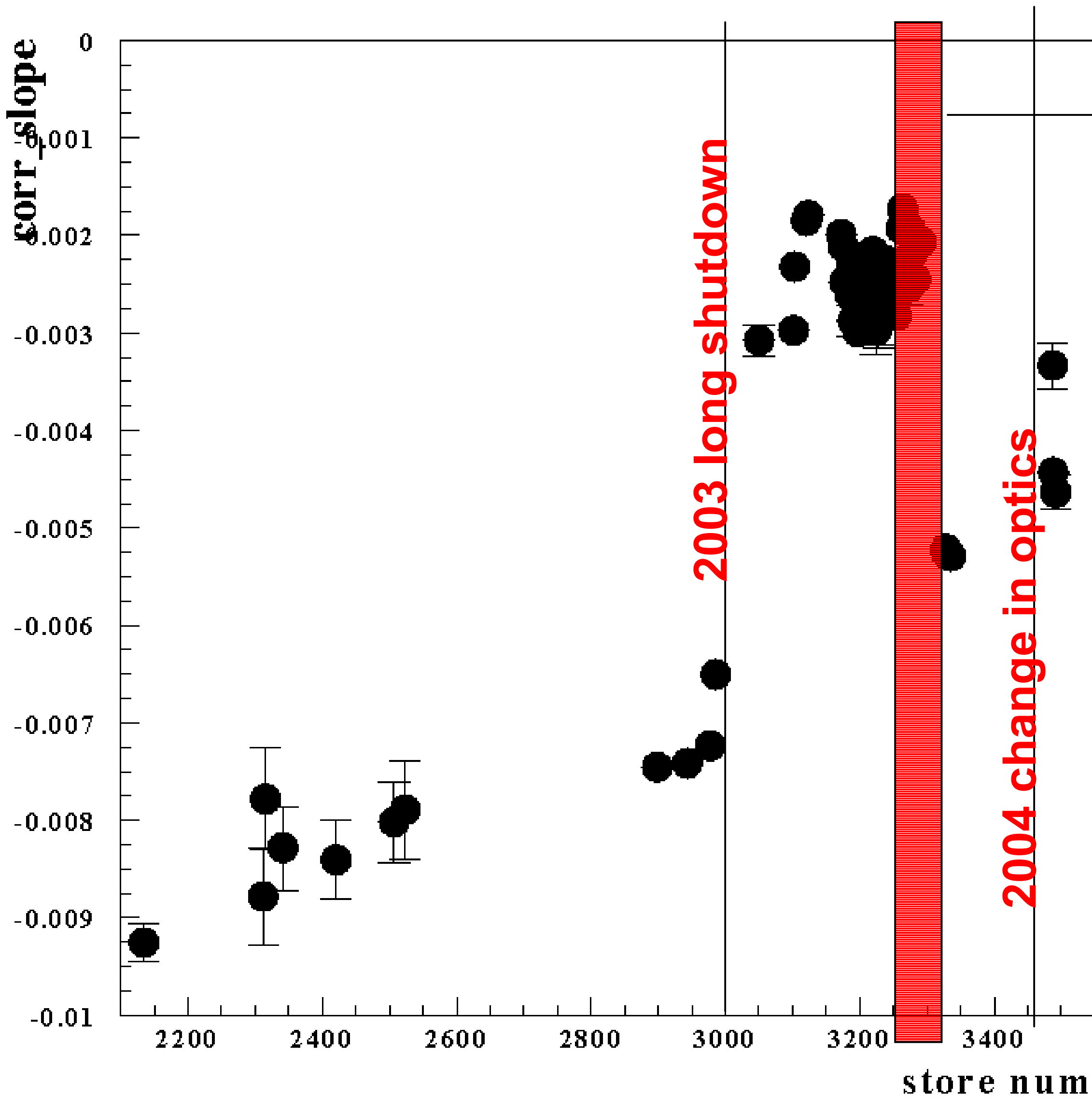
Large statistics run





Our data can be fitted with this model, but the β* for each beam would have to be smaller than 35cm…..

History of coupling

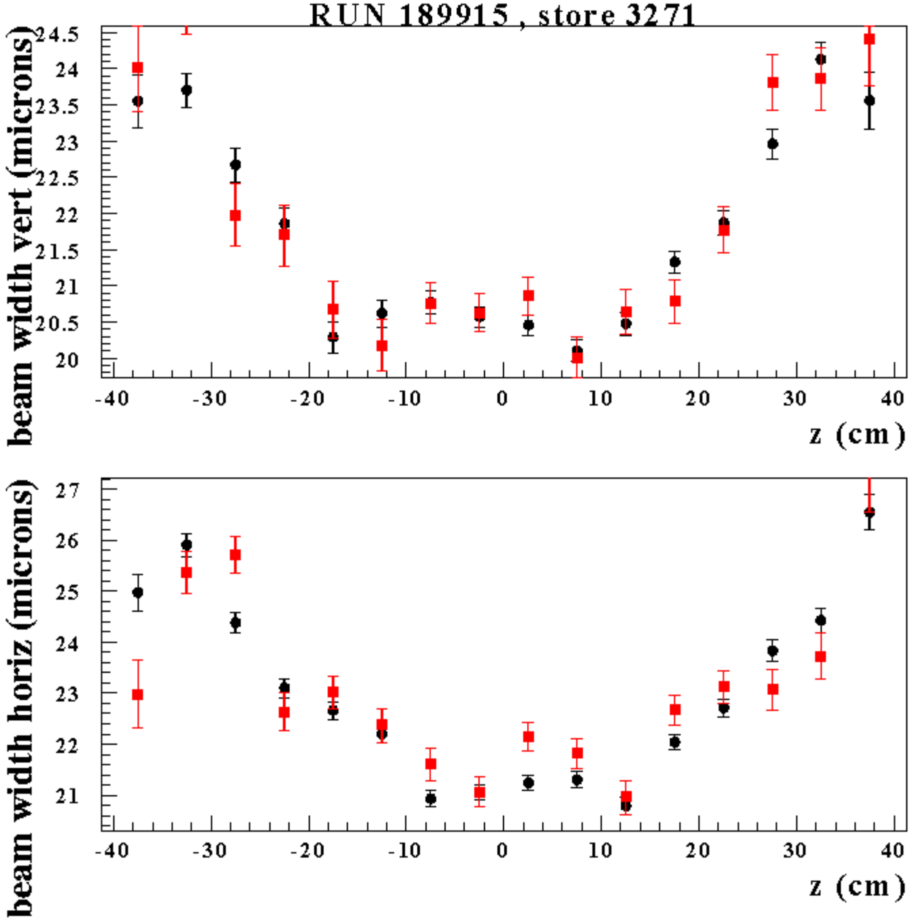


Something happened here that increased the coupling significantly.

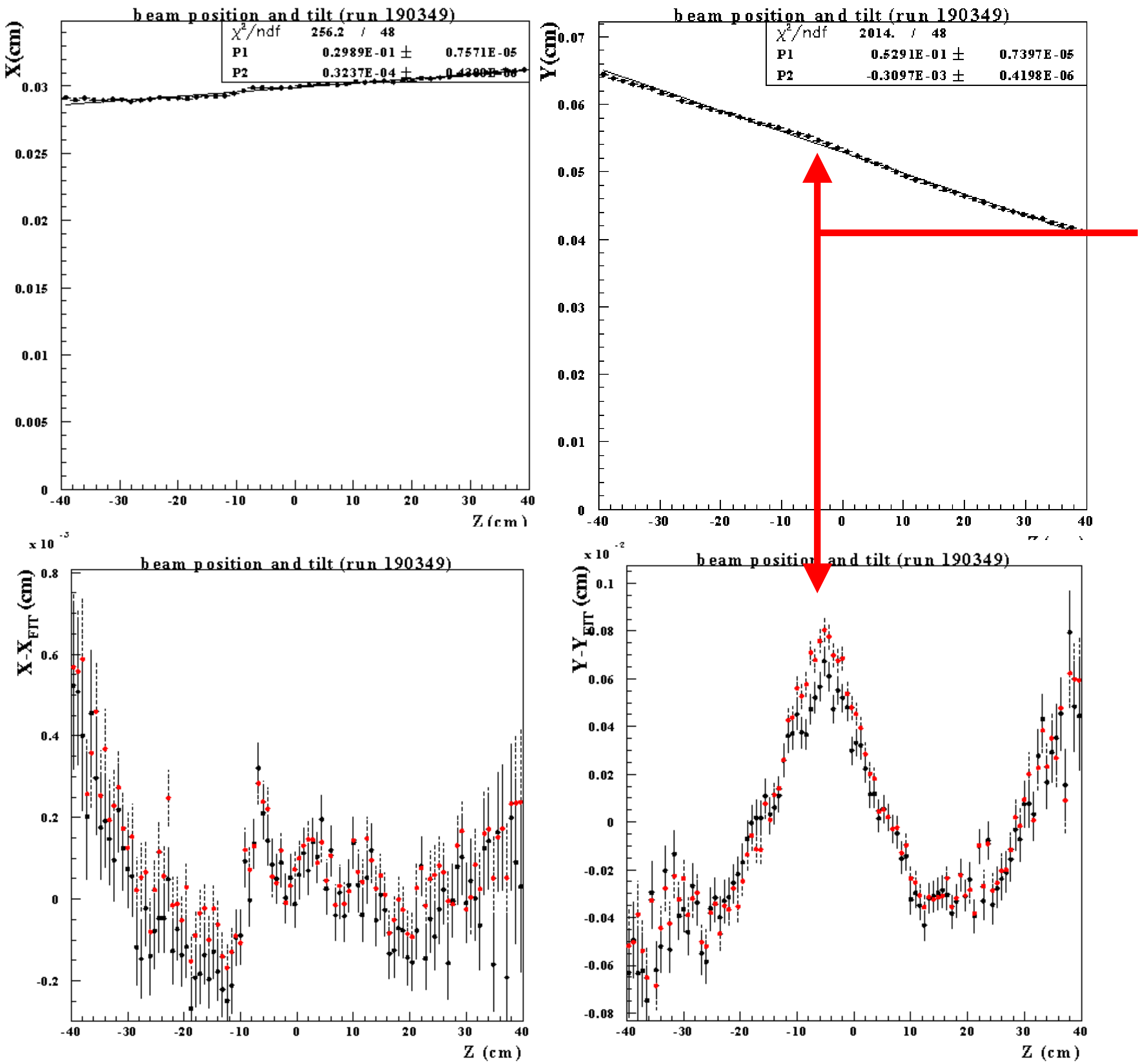
Geometry check result

- Using a new geometry file re-reconstructed and old run with the new geometry file. This test indicates that the geometry file has nothing to do with the shape of the luminous region that we are seeing.

The red points are produced using the new geometry file, the black points are produced using the old geometry file. The error for the red point is larger, because some reco jobs crashed.



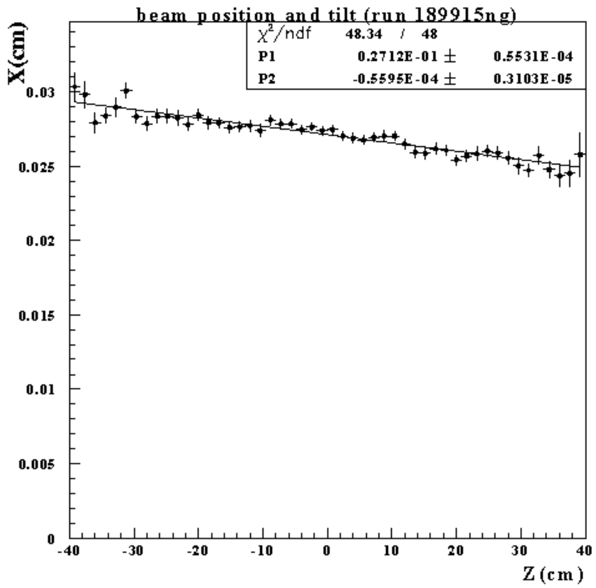
Old Geometry

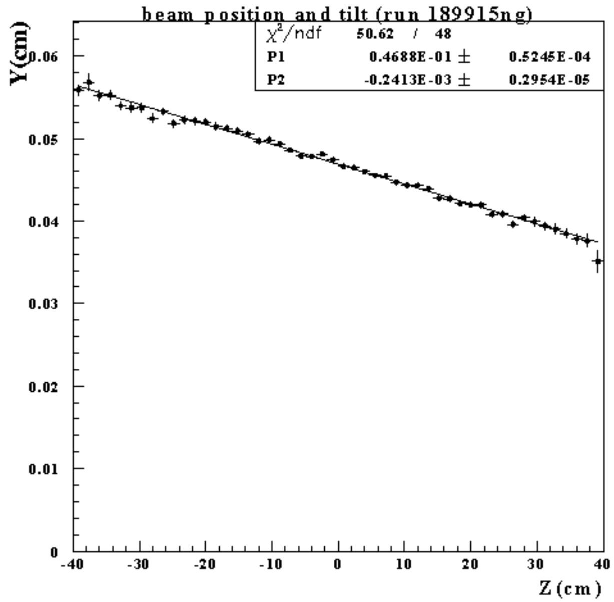


As I mentioned here before, we were seeing the beam bending inside our detector. A straight line does not represent the position of the beam in our detector.

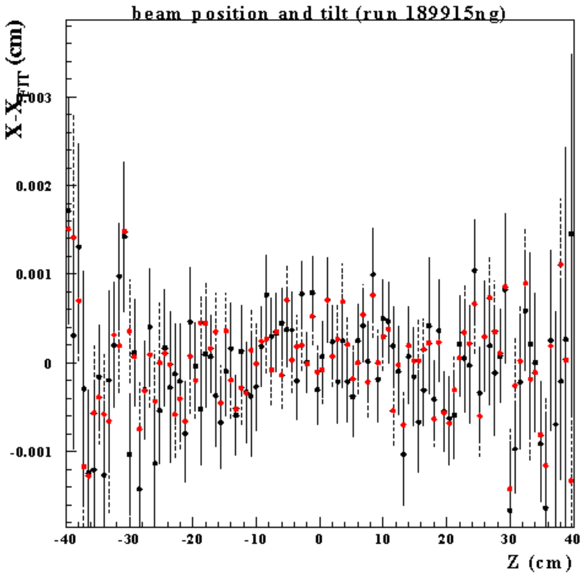
We suspected that this could be due to a geometry problem.

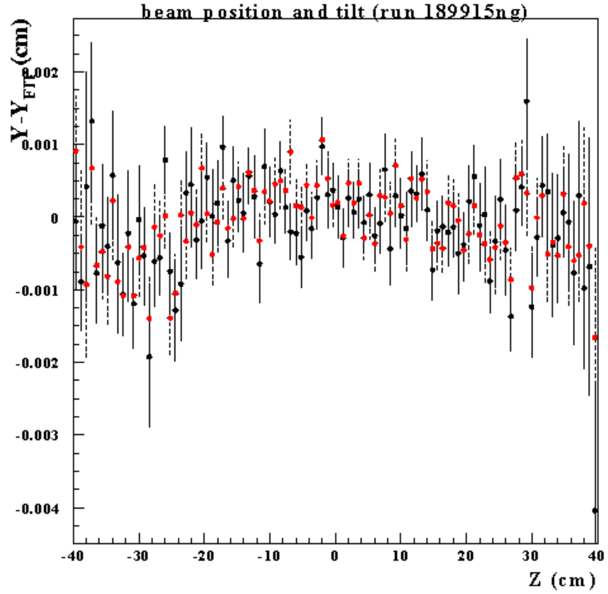
New geometry



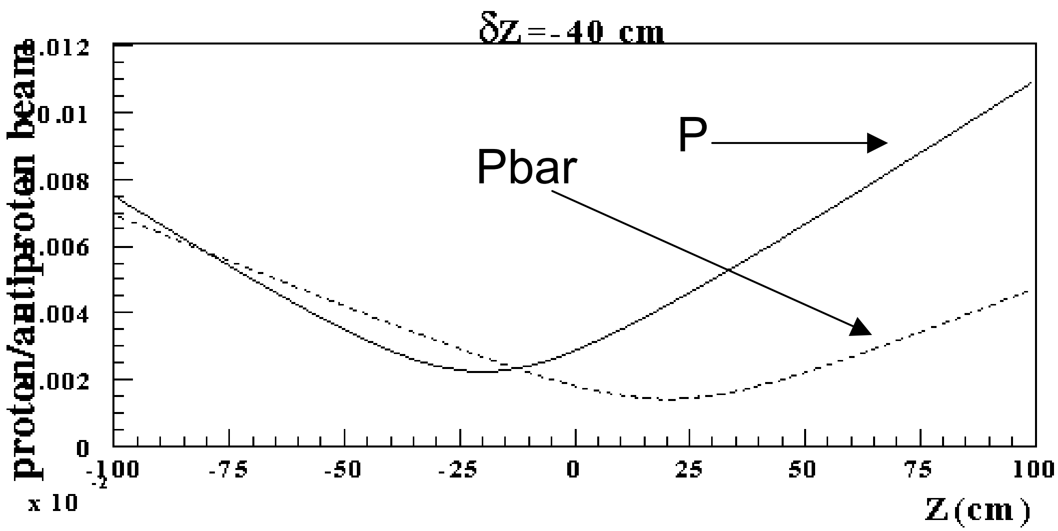


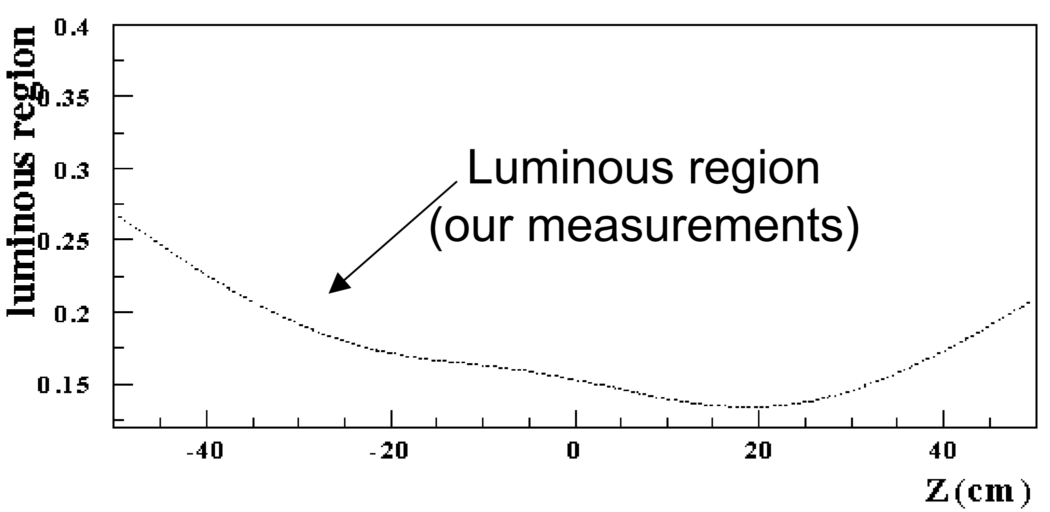
The bend is not there anymore….





Is this at all possible?





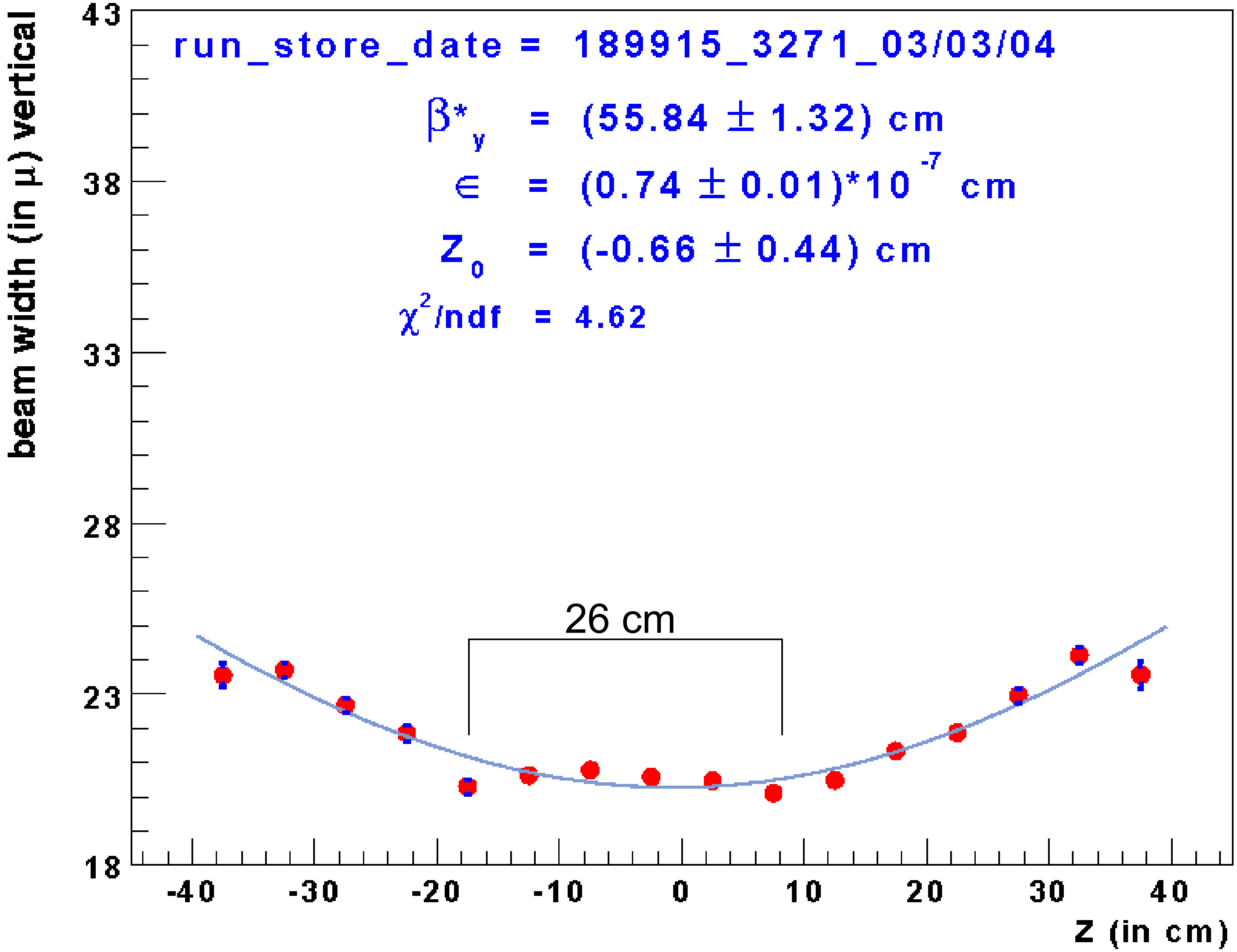
Our data is consistent with something like this.

Question to answer:

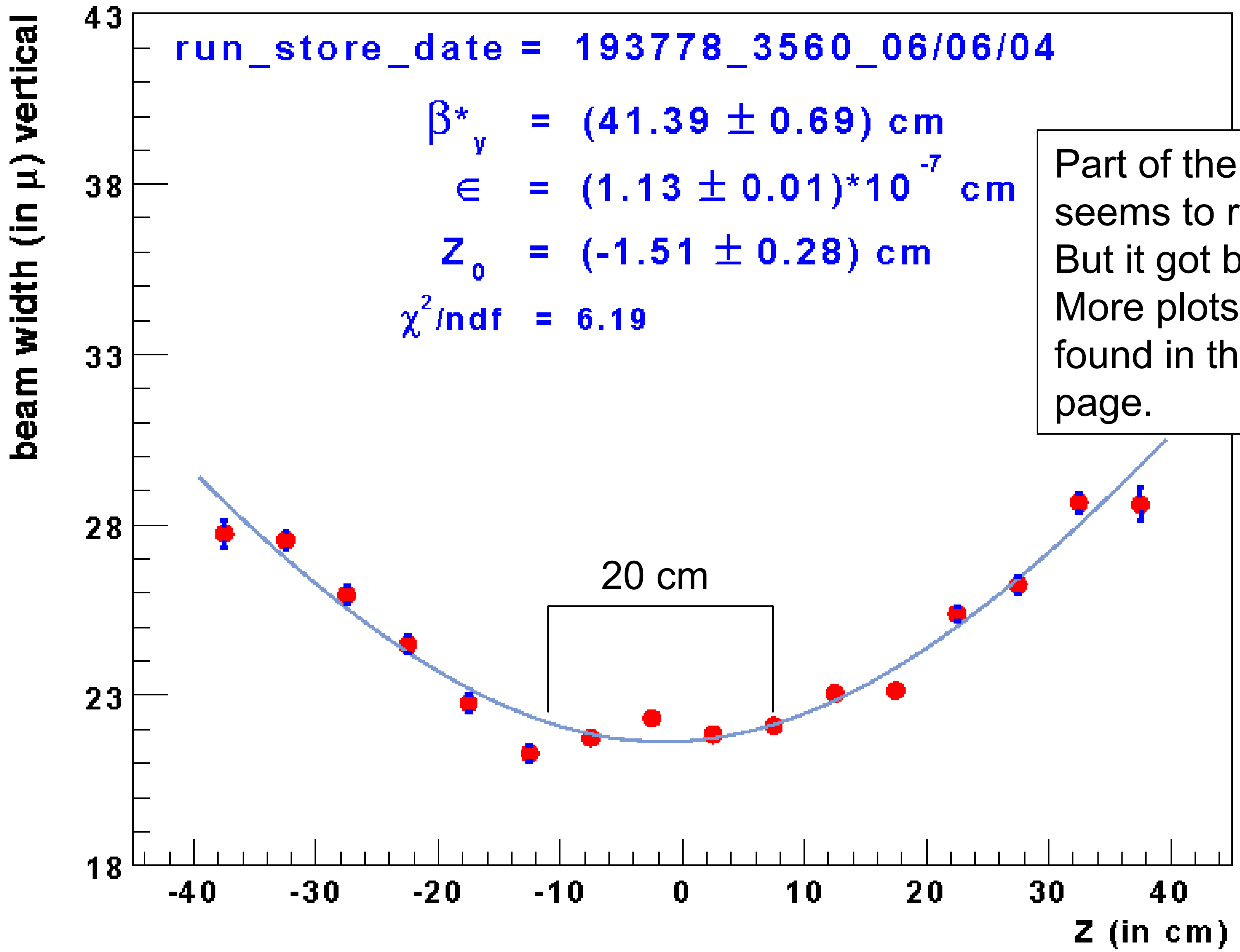
- Is this possible? (Yes, in theory)
- What needs to go wrong to get this problem in the IP?
- Do we have any evidence that tells us that this is not happening?

β^* for the luminous region looks larger than for each beam.

Before the optic change (vertical)



After the optics change (vertical)



Part of the problems seems to remain. But it got better. More plots can be found in the web page.

measurement of the shape of the luminous region

vertex method

$$\sigma^2_{obs} = \sigma^2_{beam} + k \times \sigma^2_{vertex}$$

Uses:

•coordinates of the reconstructed vertexes

•estimated errors on this vertexes

Assumes:

•unbiased reconstructed vertex position

•error estimation proportional to the real error

pair of tracks method

$$d_i = y\cos(\varphi_i) - x\sin(\varphi_i)$$

$$\langle d_1 d_2 \rangle = \sigma^2_F \cos(\varphi_1 - \varphi_2)$$

Uses:

•track parameters

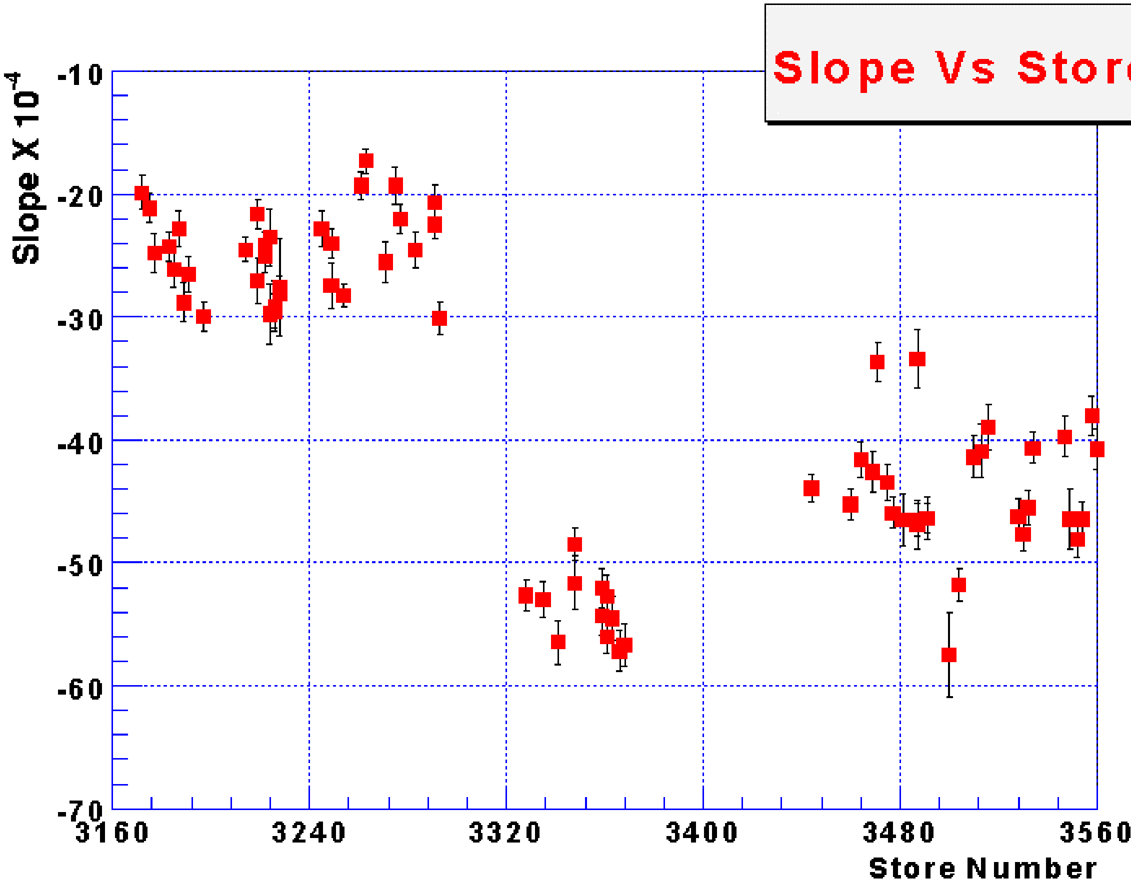
Assumes:

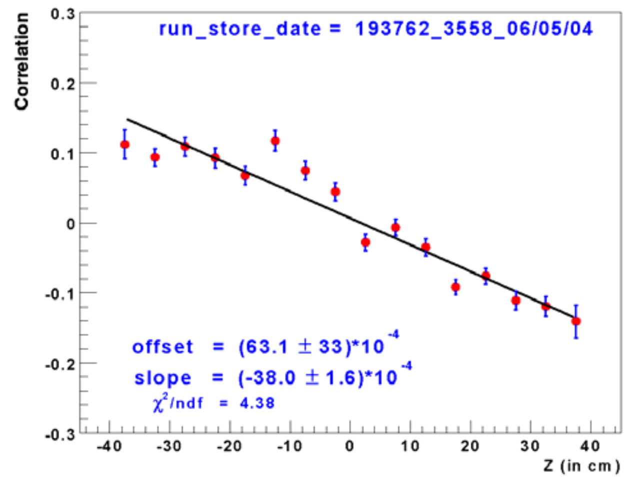
•unbiased track parameters

•uncorrelated errors in the track parameters

Here I assume circular beam, but in our calculation we do not make this assumption (formula a bit more complicated).

Other changes in the optics





As far as I know, we do not understand why this changes in the coupling after the long shutdown (last time I talked about this was Tevatron meeting of May 21). There are some ides, and people thinking about this.